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Li-Fi Architecture and Network Access Through it

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Abstract

Whether you're using wireless internet in a coffee shop, stealing it from the guy next door, or competing for bandwidth at a conference, you've probably gotten frustrated at the slow speeds you face when more than one device is tapped into the network. As more and more people and their many devices access wireless internet, clogged airwaves are going to make it increasingly difficult to latch onto a reliable signal.But radio waves are just one part of the spectrum that can carry our data. What if we could use other waves to surf the internet? One German physicist, DR. Harald Haas, has come up with a solution he calls "Data through Illumination" taking the fiber out of fiber optics by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. It's the same idea behind infrared remote controls, but far more powerful. Haas says his invention, which he calls D-Light, can produce data rates faster than 10 megabits per second, which is speedier than your average broadband connection. He envisions a future where data for laptops, smartphones, and tablets is transmitted through the light in a room. And security would be a snap—if you can't see the light, you can't access the data. Li-Fi is a VLC visible light communication, technology developed by a team, the term Li-Fi was coined by streaming high-definition video from a standard LED lamp. Li-Fi is now part of the Visible Light Communications (VLC) PAN IEEE 802.15.7 standard. Li-Fi is typically implemented using white LED light bulbs. These devices are normally used for illumination by applying a constant current through the LED. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. Unseen by the human eye, this variation is used to carry high-speed data.

***Keyword**: LIFI Architecture, LIFI Implementation, LIFI Advantages, LIFI Design*

1. Introduction

In simple terms, Li-Fi can be thought of as a light-based Wi-Fi. That is, it uses light instead of radio waves to transmit information. And instead of Wi-Fi modems, Li-Fi would use transceiver-fitted LED lamps that can light a room as well as transmit and receive information. Since simple light bulbs are used, there can technically be any number of access points. This technology uses a part of the electromagnetic spectrum that is still not greatly utilized- The Visible Spectrum. Light is in fact very much part of our lives for millions and millions of years and does not have any major ill effect. Moreover, there is 10,000 times more space available in this spectrum and just counting on the bulbs in use, it also multiplies to 10,000 times more availability as an infrastructure, globally.

It is possible to encode data in the light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. The LED intensity is modulated so rapidly that human eyes cannot notice, so the output appears constant. More sophisticated techniques could dramatically increase VLC data rates, Li-Fi, as it has been dubbed, has already achieved blisteringly high speeds in the lab. Researchers at the Heinrich Hertz Institute in Berlin, Germany, have reached data rates of over 500 megabytes per second using a standard white-light LED. Haas has set up a spin-off firm to sell a consumer VLC

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transmitter that is due for launch next year. It is capable of transmitting data at 100 MB/s - faster than most UK broadband connections.

Harald Haas, a professor at the University of Edinburgh who began his research in the field in 2004, gave a debut demonstration of what he called a Li-Fi prototype at the TED Global conference in Edinburgh on 12th July 2011. He used a table lamp with an LED bulb to transmit a video of blooming flowers that w as then projected onto a screen behind him so during the event he periodically blocked the light from lamp to prove that the lamp was indeed the source of incoming data and at TED Global, he demonstrated a data rate of transmission of around 10Mbps later on within two months he achieved 123Mbps.

2. LI-FI DESIGN

Li-Fi architecture consists of numbers of Led bulbs. Important factors shouuld consider while designing Li-Fi are as following:

- Presence of Light
- Line of Sight(Los)

for better performance use fluorescent light &LED.

As shown in figure 2 streaming content must have proper integration with server & internet network, so that it is easily possibble to work efficiently.

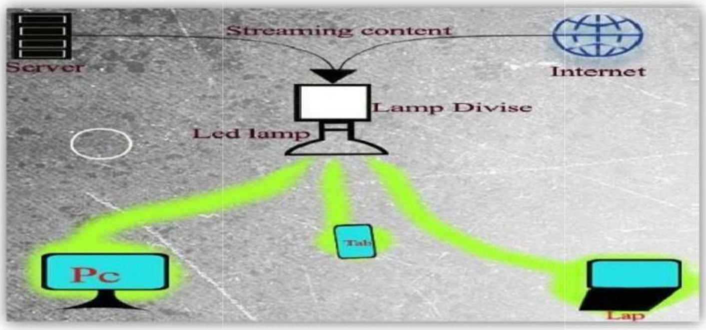

Figure 1. LiFi Working

2.1-Performance of LI-FI

The main components of a simple system based on Li-Fi are:

i) High brightness LED which acts as the communication source

ii) Silicon photodiode which serves as the receiving element

Data from the sender is converted into an intermediate data representation i.e. byte format and then converted into light siignals which are emitted by the transmitter. The light signal is received by the photodiode at the receiver side. The reverse process takes placee at the destination computer to retrieve the data back from the received light. LEDs are employed as the light sources. The model transmits digital signal by means of direct modulation of the light. The emitted light is detected by an optical receiver an d different module of LiFi are:

- **Source Computer**: Data Reading Module →Data Conversion Module→Transmmitter Module
- **Destination Computer**: Receiver Module →Data Interpretation Module →Data Display (GUI)

- **Data Conversion Module** – converts data into bytes so that it can be represented as a digital signal. It can also encrypt the data before conversion.
- **Transmitter Module** – gennerates the corresponding on-off pattern for the LEDs.
- **Receiver Module** – has a photo diode to detect the on and off states of thee LEDs.
- **Data Interpretation Module** – converts data into the original format. If encryption was done, it also performs decryption.

Li-Fi is typically implem ented using white LED light bulbs at the downlink transmitter. These devices are normally used for illumination only by applying a constant current. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This very property of optical current is used in Li-Fi setup. The operational procedure is very simple-, if the LED is on, you transmit a digital 1, if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data. Hence all that is required is some LEDs and a controller that code data into those LEDs. All one has to do is to vary the rate at which the LED's flicker depending upon the data we want to encode. Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light's frrequency with each frequency encoding a different data channel. Such advancements promise a theoretical speed of 10Gbps meaning one can download a full high-definition film in just 30 seconds.

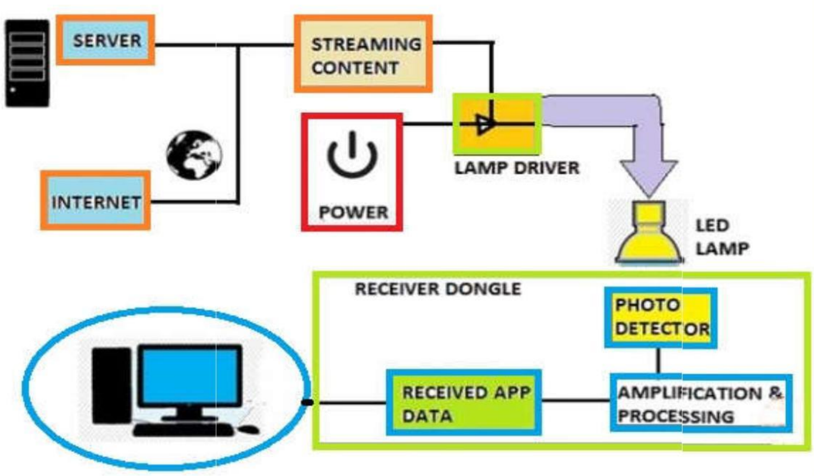

Figure 2. LiFi Implementation

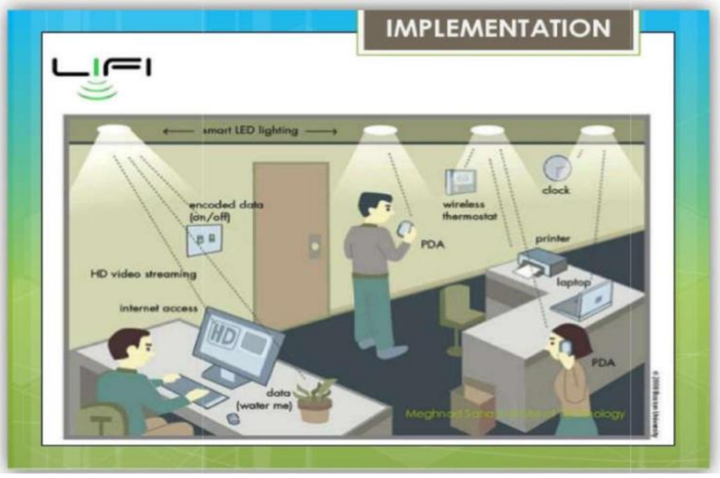

Figure 3. LiFi Implementation2

3. Working of Li-Fi

3.1 General Working Principle

Light emitting diodes (LEDs) can be switched on and off faster than the human eye can detect since the operating speed of LEDs is less than 1 μs, thereby causing the light source to appear to be continuously on. This invisible on-off activity enables data transmission using binary codes. Switching on an LED is binary ‘1’, switching it off is binary ‘0’. It is possible to encode data in light by varying the rate at which LEDs flicker on and off to give different strings of 1s and 0s. Modulation is so rapid that humans cannot notice it. A light sensitive device (photo detector) then receives the signal and converts it back into original data.

This method of using rapid pulses of light to transmit information wirelessly is technically referred to as Visible Light Communication (VLC). The term Li-Fi has been inspired due to its potential to compete with conventional Wi-Fi. The VLC uses visible light between 400 THz (780 nm) and 800 THz (375 nm) as the optical carrier for data transmission and for illumination.

Data rates of greater than 100 Mbps can be achieved by using high speed LEDs with adequate multiplexing. Parallel data transmission using arrays of LEDs where each LED transmits a separate stream of data can be used to increase the VLC data rate. Though the lights have to be kept on in order to transmit data, they can be dimmed to the point that they are not visible to humans but still be capable of transmitting data.

3.2 Technical Aspects and Modulation

VLC in LI-Fi refers to any use of the visible light portion of the electromagnetic spectrum to transmit information. A VLC interest group is certified by the IEEE 802.15 with the final standard being approved in 2011. The standard of VLC specifies VLC consisting of mobile-to-mobile (M2M), fixed-to-mobile (F2M) and infrastructure-to-mobile (I2M) communications. The main purpose of VLC is to focus on medium-range communications for intelligent traffic systems at low-speed and on short-range mobile to mobile and fixed to mobile communications at high speeds to exchange data. Data rates are supported from some 100 kbps up to 100 Mbps using various modulation schemes, Li-Fi communication is modeled after protocols established by the IEEE 802 workgroup. It defines physical layer (PHY) & media access control (MAC) layer for VLC/Li-Fi and the MAC layer supports 3 multi-access technologies i.e. peer-to-peer, star configuration and broadcast mode. It also handles physical layer management issues such as addressing, collision avoidance and data acknowledgement protocols. The physical layer is divided into 3 types: PHY I, II, III and employ a combination of different modulation schemes, in order to actually send out data by means of LEDs, it is required to modulate these into a carrier signal. The carrier signal consists of light pulses sent out at short intervals. The manner in which this is done depends on the modulation scheme employed.

3.3 Li-Fi systems Modulation Schemes

3.3.1 **On-Off Keying (OOK)**: The 802.15.7 standard uses Manchester coding so that the period of positive pulses is same as the period of negative ones, however this doubles the bandwidth required for transmission. For higher bit rates, run length limited (RLL) coding is used which is spectrally more efficient. Dimming is supported by adding an OOK extension which adjusts the aggregate output to the correct level.

3.3.2 **Variable Pulse Position Modulation (VPPM):** PPM encodes the data using the position of the pulse within a set time period. The duration of the period containing the pulse must be long enough to allow different positions to be identified. VPPM is similar to PPM but it allows the pulse width to be controlled to support light dimming.

3.3.3 **Colour Shift Keying (CSK)** is used if the illumination system uses RGB-type LEDs. By combining different colours of light, the output data can be carried by the colour itself and hence the intensity of the output can be near constant. Mixing of RGB primary sources produces different colours which are coded as information bits. The disadvantage is that it increases the complexity of the transceivers.

3.3.4 **Sub-Carrier Inverse PPM (SCIPPM)** is divided into two parts sub-carrier part and DC part. The DC part is used only for lighting or indicating. When there is no requirement for lighting or indicating, SCPPM (Sub-Carrier PPM) is used in order to save energy.

3.3.5 **Frequency Shift Keying (FSK)**: In this method, data is represented by varying the frequencies of the carrier signal. Before transmitting two distinct valuues (0 and 1), there needs to be two distinct frequencies.

3.3.6 **SIM-OFDM (Sub-Carrier Index Modulation OFDM):** This is a new approach to transmission in which an additional dimension is added to conventional 2D amplitude/phase modulation (APM) techniques such as quadrature amplitude modulation (QAM) and amplitude shift keying (ASK). The key idea is to use the sub-carrier index to convey information to the receiver.

3.4 LED as Light Source

The most important requirement for a light source in order to serve communication purposes is the ability to be switched on and off repeatedly in very short intervals of time. Due to their ability to be switched on and off rapidly, LEDs are suitable lightsources forr Li-Fi. LEDs offer many benefits over fluorescent lamps and incandescent lamps such as higher efficiency, environment-friendly manufacturing, flexibility of design, longer useful lifetimes and improved spectrum performance and LEDss emit light when the energy levels change in the semiconductor diode. This change in energy generates photons, some of which are emittted as light. The wavelength of emitted light deepends upon the difference in energy levels and the type of semiconductor material used to form the LED chip. Solid-state design allows LEDs to withstand vibration, shocks, frequent switcching and extremes of environment without compromising their long useful lives of typically more than 100,000 hours and the basic LED consists of a semiconductor diode chip mounnted in the reflector cup of a lead frame that is connected to electrical (wire bond) wires, and then encased in a solid epoxy lens. The variations in data rate with the size of LEDs are very important in Li-Fi technology. Different data rates can be achieved with different sized LEDs. Normal sized LED bulbs can be reduced to micro-L EDs which handle millions of variations in light intensity. A micro-LED light bulb can transmit 3.5 Gbps and data rates of more than 10 Gbps are possible. The micro LED bulbs allow the light stream to be beamed in parallel thereby transmitting huuge amounts of data in terms of Gbps.

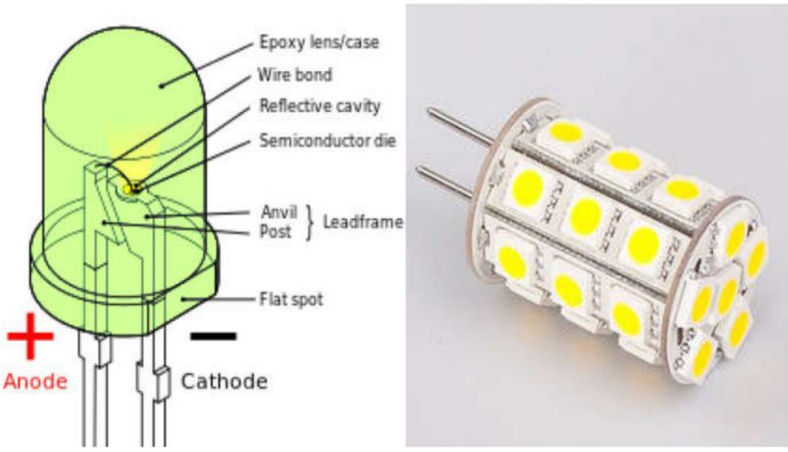

Figure 4. LED Working

3.5 Use of Model LiFi

In local Li-Fi cloud, several data based services are supported through a heterogeneous communication system. Initially, the Li-Fi Consortium defined different types of technologies to offer secure, reliable and ultra-high-speed wireless communication interfaces. Thhese included giga-speed technologies, optical mobility technologies and navigation, precision location and gesture recognition technologies. For giga-speed technologies, the Li-Fi Consortium defined Giga Dock, Giga Beam, Giga Shower, Giga Spot and Giga MIMO models to tackle different user scenarios; includes wireless charging for smart phones tablets or notebooks, with speeds up to 10 Gbps. Meanwhile, the Giga Beam model is a point-to-point data link for kiosk applications or portable-to-portable data exchanges. Thus a two-hour full HDTV movie (5 GB) can be transferred from one device to another within four seconds while Giga Shower, Giga Spot and Giga-MIMO are the other in-house communication models. On one side, a transmitter or receiver is mounted into the ceiling connected to, say, a media server. On the other side are portable or fixed devices on a desk in an office, in an operating room, in a production hall or at an airport. Giga Shower provides unidirectional data services via many channels to multiple users with gigabit-class communication speed over several meters. This is like watching TV channels or listening to different radio stations where no uplink channel is needed. In case Giga Shower is used to sell books, music or movies, the connected media server can be accessed via Wi-Fi to process payment via a mobile device. Giga Spot and GigaMIMO are optical wireless single- and multi-channel Hot Spot solutions offering bidirectional gigabit-class communication in a room, hall or shopping mall for example.

4. Applications

Li-Fi technology finds application in a wide variety of fields like

4.1 Medical and Healthcare

Due to concerns over radiation, operating rooms do not allow Wi-Fi and even though Wi-Fi is in place in several hospitals, interferences from computers and cell phones can block signals from medical and monitoring equipment. Li-Fi solves these problems. Lights are an essential part of operating rooms and Li-Fi can thus be used for modern medical instruments. Moreover, no electromagnetic interference is emitted by Li-Fi and thus it does not interfere with any medical instruments such as MRI scanners.

4.2 Airlines and Aviation

Wi-Fi is often prohibited in aircrafts. However, since aircrafts already contain multiple lights, thus Li-Fi can be used for data transmission.

4.3 Power Plants and Hazardous Environments

Wi-Fi is not suitable for sensitive areas like power plants. However, power plants still require fast and interconnected data systems for monitoring grid intensity, demand, temperature etc. In place of Wi-Fi, Li-Fi can provide safe connectivity throughout the power plant. Li-Fi offers a safe alternative to electromagnetic interference due to radio waves in environments such as petrochemical plants and mines.

4.4 Underwater Explorations and Communications

Remotely operated underwater vehicles or ROVs work well except in situations when the tether is not long enough to fully explore an underwater area or when they get stuck. If instead of the wires, light were used then the ROVs would be freer to explore. With Li-Fi, the headlamps could also then be used to communicate with each other, data processing and reporting findings back to the surface at regular intervals, while also receiving the next batch of instructions. Radio waves cannot be used in water due to strong signal absorption. Acoustic waves have low bandwidth and disrupt marine life. Li-Fi offers a solution for conducting short-range underwater communications.

4.5 Traffic

Li-Fi can be used for communications between the LED lights of cars to reduce and prevent traffic accidents. LED headlights and tail-lights are being implemented for different cars. Traffic signals, signs and street lamps are all also transitioning to LED. With these LED lights in place, Li-Fi can be used for effective vehicle-to-vehicle as well as vehicle-to-signal communications. This would of course lead to increased traffic management and safety.

4.6 GigaSpeed Technology

The Li-Fi Consortium provides the fastest wireless data transfer technology presently available. Our current solutions offer effective transmission rates of up to 10 Gbps, allowing a 2-hour HDTV film to be transferred in less than 30 seconds. This can be extended to several 100 Gbps in future versions.

4.7 Spatial Reuse

Li-Fi can act as an alternative in regions with high density wireless communication where 500 or more users may be contending for Wi-Fi. This would lead to low access speeds for the users. Li-Fi can be used to share some of the load of Wi-Fi.

4.8 Smart Class

Li-Fi can find application in the new smart class technology which is quickly becoming imperative for progressive schools and colleges in the world. Using this technology, teachers show the class a 2D/3D animation on a large screen. They can explain different topics, zoom in to show the important details and freeze and annotate for appropriate emphasis. Through engaging animations, colours and sounds, the teachers gain the full attention of every child in the class. Each child gets visual input on what, where, when and how anything happens and the concepts are well understood. In this technology all the computers are connected to the server using wired LAN technology. The physical transmission medium for wired LAN involves cables, either twisted pair or fiber optics.

5. Advantages of LiFi Network

- Li-Fi can solve problems related to the insufficiency of radio frequency bandwidth because this technology uses Visible light spectrum that has still not been greatly utilized.
- High data transmission rates of up to 10Gbps can be achieved.
- Since light cannot penetrate walls, it provides privacy and security that Wi-Fi cannot.
- Li-Fi has low implementation and maintenance costs.
- It is safe for humans since light, unlike radio frequencies, cannot penetrate human body. Hence, concerns of cell mutation are mitigated.

6. Limitations of Li-Fi

Despite its many advantages, Li-Fi like any other technology also comes with a number of limitations and disadvantages. These are enumerated below:

- The main problem is that light cannot pass through objects, so if the receiver is inadvertently blocked in any way, then the signal will immediately be cut out. If the light signal is blocked one could switch back over to radio waves.
- Reliability and network coverage are the major issues to be considered by the companies while providing VLC services. Interference from external light sources like sunlight, normal bulbs; and opaque materials in the path of transmission will cause interruption in the communication.
- High installation cost of the systems can be complemented by large-scale implementation of VLC though adopting this technology will reduce further operating costs like electricity charges, maintenance charges etc.

We still need Wi-Fi and we still need radio frequency cellular systems. You can't have a light bulb that provides data to a high-speed moving object or to provide data in a remote area where there are trees, walls and obstacles.

7. Conclusion

Li fi is the advanced technology and Li-Fi has advantage of speed but it disadvantage is that if we want to work in darkness then we can't use this technology and other disadvantage is that we should use many lights where we should use this network.

Wireless networking is very cheap than li-Fi networking. It is believed that LiFi is more powerful than WiFi and can transmit data in the range of Giga bits per second however there may arise various difficulties which may involve in prototyping and usage of LiFi equipment's and the technology is yet to be fully formed and commercialized. The technology mainly uses LED bulbs to transfer data to equipments with photoreceptive adapters to receive data. This can soon substitute the normal method of internet sharing, also extending the capabilities to new possibilities.

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